Title

Robust determination of rock anisotropy in the laboratory using laser ultrasonics

Authors

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Abstract

Robust characterization of rock anisotropy is the preferred laboratory method to support seismic data interpretation in the field. Especially in shale formations, accurate elastic anisotropy helps delineate subsurface stress distribution, improve seismic imaging, and enhance hydraulic fracturing design. The conventional technique for evaluating rock elastic anisotropy involves ultrasonic pulse transmission between source and receiver transducers attached to the rock surface. The size, position and orientation of the source and receiver in relation to the propagation distance and direction, and their coupling to the rock surface introduce undesired uncertainties in Thomsen's anisotropy parameters and rock attenuation: effective propagation distance; group or phase velocity; impact of the contact interface on measured wave attenuation; impact of heterogeneity on wave velocity measurements. We apply here the contactless laser ultrasonic method, involving a source laser (short-pulse high-peak power), a probing laser (vibrometer), and a cylindrical rock sample set on a rotating stage. The footprint of the source laser beam is 2 mm, and that of the receiver beam is 0.1 mm, which can conveniently be approximated by a point on a centimetric rock sample. The propagation distance is hence unambiguously known, implying that a group velocity is effectively estimated, and the observed attenuation is solely due to the rock, not to the rock-transducer interface (extrinsic). The technique also allows for a denser ultrasonic probing. Four samples are probed, where the P-wave velocity along up to 630 independent ray paths is evaluated. Three samples are made of a known, homogeneous, and layered synthetic material phenolic grade, approximately transversely isotropic. These samples were cored along, across and at 45° to the layers. The fourth sample is a heterogeneous shale from the Goldwyer formation (Canning basin, Western Australia). The measurements on the three known phenolic samples are used to validate the method, and optimise the measurement protocol. Application of the method to the unknown heterogeneous shale suggests that (i) anisotropy can be reliably estimated in the homogeneous sub-volume of the sample and that (ii) the mineralogical heterogeneity can be detected and identified in other sub-volume.